

DC Local Power Distribution with Microgrids and Nanogrids

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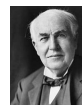


Context

- “Local” – within a building (or campus)
 - Not involving utility grid
- “Power Distribution”
 - “Technology / infrastructure that moves electrons from devices where they are available to devices where they are wanted”

Grid terminology

- **Microgrid** Capability
 “... a group of interconnected loads and distributed energy resources A microgrid can connect and disconnect from the grid to enable it to operate in both **grid-connected or island-mode**”
(US Dept. of Energy)
CIGRE defn. includes microgrids never connected to utility grid
- **Nanogrid** Simplicity
 “A **single domain of power**; single voltage, frequency (if AC), reliability, quality, capacity (power), price, and administration. Storage is internal to a nanogrid.” Generation forms its own nanogrid. *(Nordman, 2010)*
- **Picogrid** Singularity
 An **individual device with its own internal battery** for operation when external sources are not available or not preferred, and managed use of the battery. *(S. Ghai et al. in e-energy 2013; paraphrased)*

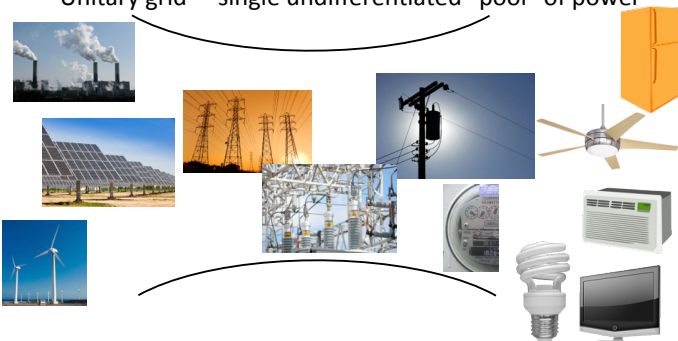


133 ... 84 years later

Generation	End use	Distribution

Traditional power distribution

“Unitary grid” - single undifferentiated “pool” of power



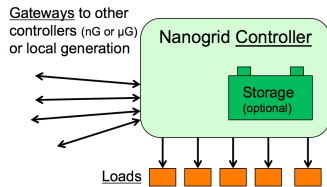
- Enormously complex but only lightly managed

Myth of uniform power availability

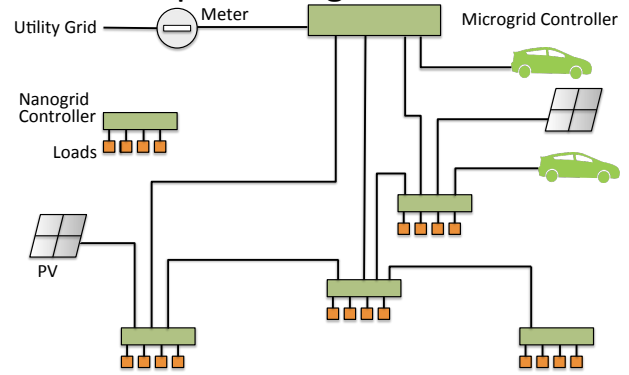
- Electricity is not equally available across space and time
 - Has long been true within utility grid
 - “Locational Marginal Price”
 - Increasingly true within buildings
 - Local storage and/or generation, islanded grids, or capacity constraints, combined heat-and-power
- Technology we have today presumes uniform availability
- Dynamic pricing at meter a needed starting point
 - Grid can express preferences to customer

What is a Nanogrid?

- Smallest unit of power distribution
- Single physical layer (voltage; usually DC)
- Single domain: administration, reliability, quality, and **price**
- Can interoperate with other local grids through gateways
 - Generation forms own nanogrid
 - Only two device types: grid controller and load
- In fully-functioning nanogrid, all links include communications
 - Gateways to other controllers (nG or μ G) or local generation
- Wide range in technology, capability, capacity

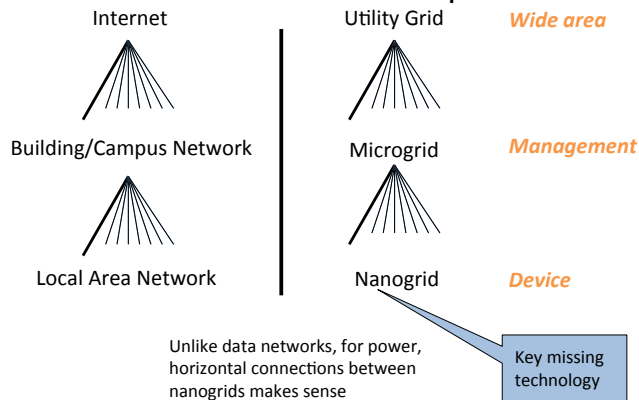


Example local grid network



All connections peer-to-peer and can be changed dynamically
Price is how devices know which way power should flow

Scaling structure — communications and power



Paradigms

Old phone system	Internet
Utility grid	Local Power Distribution
19 th century	20 th /21 st century
Centralized	Distributed
No storage	Storage widespread
Tightly coupled	Loosely coupled
Entangled technology	Isolated technologies
Custom / Expensive	Commodity / Cheap
.....

Power distribution & communications

“Technology / infrastructure that moves electrons from devices where they are available to devices where they are wanted”

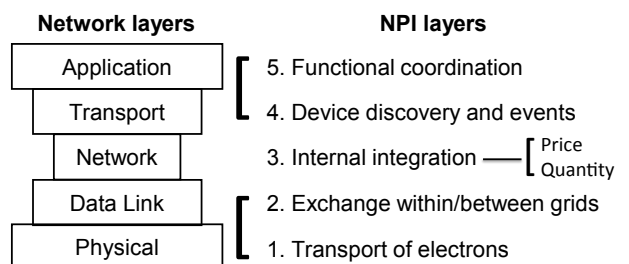
- Important *similarities* between moving bits and moving electrons
- Important *differences* between moving bits and moving electrons

All bits/packets different; all electrons same

- Routing power makes no sense
- Only care about timing, location, quantity

Layered model for device operation for Local Power Distribution

Network Power Integration



LPD benefits

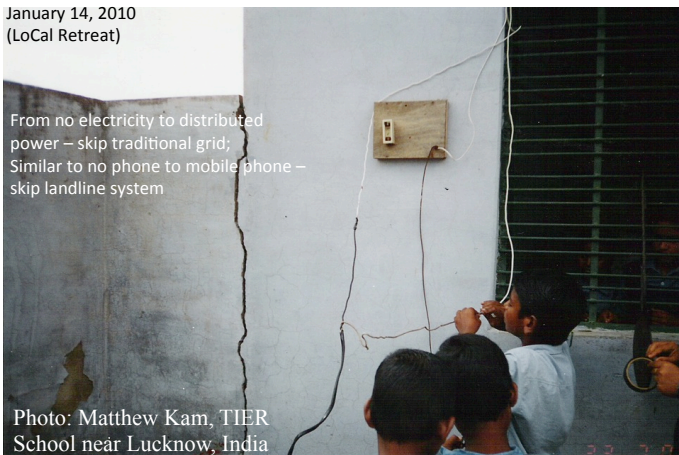
- Guarantee reliability locally - with nanogrids – only for critical loads
- Enable easy use of DC for many purposes
- Enable Direct DC, for efficiency, reliability
- Add generation, storage, and managed loads organically
- Local generation and storage plug-and-play
 - Inexpensive, easy to add/change
- Inter-building power links easy to implement
- Can be a universal technology
- LPD inherently much more secure than alternatives
 - Only communicate with entities with direct wired connection

Open Questions

- How valuable would a shared medium be? What complications would that add?
- How valuable are multi-drop ports for end-use loads? What complications does that add?
- What higher capacity link technologies should be created?
- What from LPD could be applied to AC power systems?

Image from Eric Brewer talk
“Energy in the Developing World”
January 14, 2010
(LoCal Retreat)

Nanogrid Inspiration



Summary and Next Steps

- Nanogrids can be key to success of microgrids
 - Can be deployed faster, cheaper
- Key missing technologies: pricing and gateways
 - May be achievable without new circuitry
- Success indicators. Utility grids are:
 - Smaller
 - Less reliable
 - Much less costly to society

Thank you

